Kiln Systems - Overview

Urs Gasser
PT 99/14501/E

SUMMARY

Today's kiln systems for burning cement clinker of major importance use a rotary kiln. Exceptions are vertical shaft kilns still used in certain geographical areas. With very rare exceptions, new plants use the dry process. However, there are still important markets where older wet process plants are predominant (USA, Russia).

A first classification of the process can be made based on the water content of the kiln feed:

	< 1% water	dry-process
10 ...	12% water	semi-dry-process
17 ...	21% water	semi-wet-process
25 ...	40% water	wet-process

- ♦ Dry-Process
  - Precalciner kiln with 4 to 6 cyclone stages (contemporary technology):
    * Separate tertiary air duct
    * 50 - 60% fuel to the precalciner
    * Large capacities possible > 10000 t/d
    * Up to 4000 t/d in 1 string
    * Heat consumption < 3000 kJ/kg possible (6 stages)
    * Sensitive to circulation phenomena (-> kiln gas bypass!)
  - 4-stage cyclone pre-heater kiln (standard technology 1970 to 1980):
    * Cyclone stages (co-current flow) for raw meal preheating
    * Large application world wide
    * Capacities of up to 4500 t/d technically possible
    * Heat consumption: 3150 to 3350 kJ/kg cli
    * Sensitive to circulation phenomena (-> kiln gas bypass!)
  - 2-stage cyclone pre-heater kiln:
    * Less sensitive to circulation phenomena than 4-stage pre-heater
    * Higher heat consumption than pre-heater with more stages
  - Shaft pre-heater kiln:
    * Counter current heat exchange between hot gas and raw meal
    * Practical efficiency inferior to cyclone pre-heater
  - Long-dry-kiln:
    * Rather simple equipment
    * High dust emission from kiln tube
    * Without heat exchange internals: high heat consumption of up to 5100 kJ/kg cli
    * With chains and/or crosses: 4200 kJ/kg cli achievable

- Semi-dry and semi wet process
  - Grate pre-heater kiln (LEPOL, ACL):
    - Raw meal must be suitable to be nodulised with water (semi-dry)
    - 3450 kJ/kg cli (no waste heat available for primary raw material drying)
  - Long rotary kiln and suspension preheater:
    - Filter cakes fed or slurry injection into vertical dryer; rather rare cases
- Wet-process
  - Long wet kiln:
    - Fed with raw meal slurry of approx. 32 - 42% water content
    - Internal heat transfer improved by chains
    - High heat consumption of 5300 to 6300 kJ/kg cli due to evaporation of water
    - Heat consumption reduced by slurry thinners for a slurry with 25 - 30% H2O
    - Slurry preheaters can reduce kiln size and improve heat exchange

1. PROCESS REQUIREMENTS FOR KILN SYSTEMS

The kiln system has to be designed to cope with the requirements of the chemical process during which the kiln feed material is converted into cement clinker.

This process as a whole is endothermic and takes place at maximum material temperatures of 1450°C. Receiving its thermal energy from hot gases of up to 2000°C generated by combusting fuels, it is also referred to as pyroprocess.

Type of reaction and temperature development are compiled in "sequence of reactions occurring in a rotary kiln" (table 1) and graphically as the "quasi-qualitative variation of minerals with temperature" (figure 1).

The chemical process taking place in the kiln system where raw meal (input) is converted to cement clinker (output) can be subdivided into the following five steps:

1. Drying
2. Preheating
3. Calcining
4. Sintering
5. Cooling

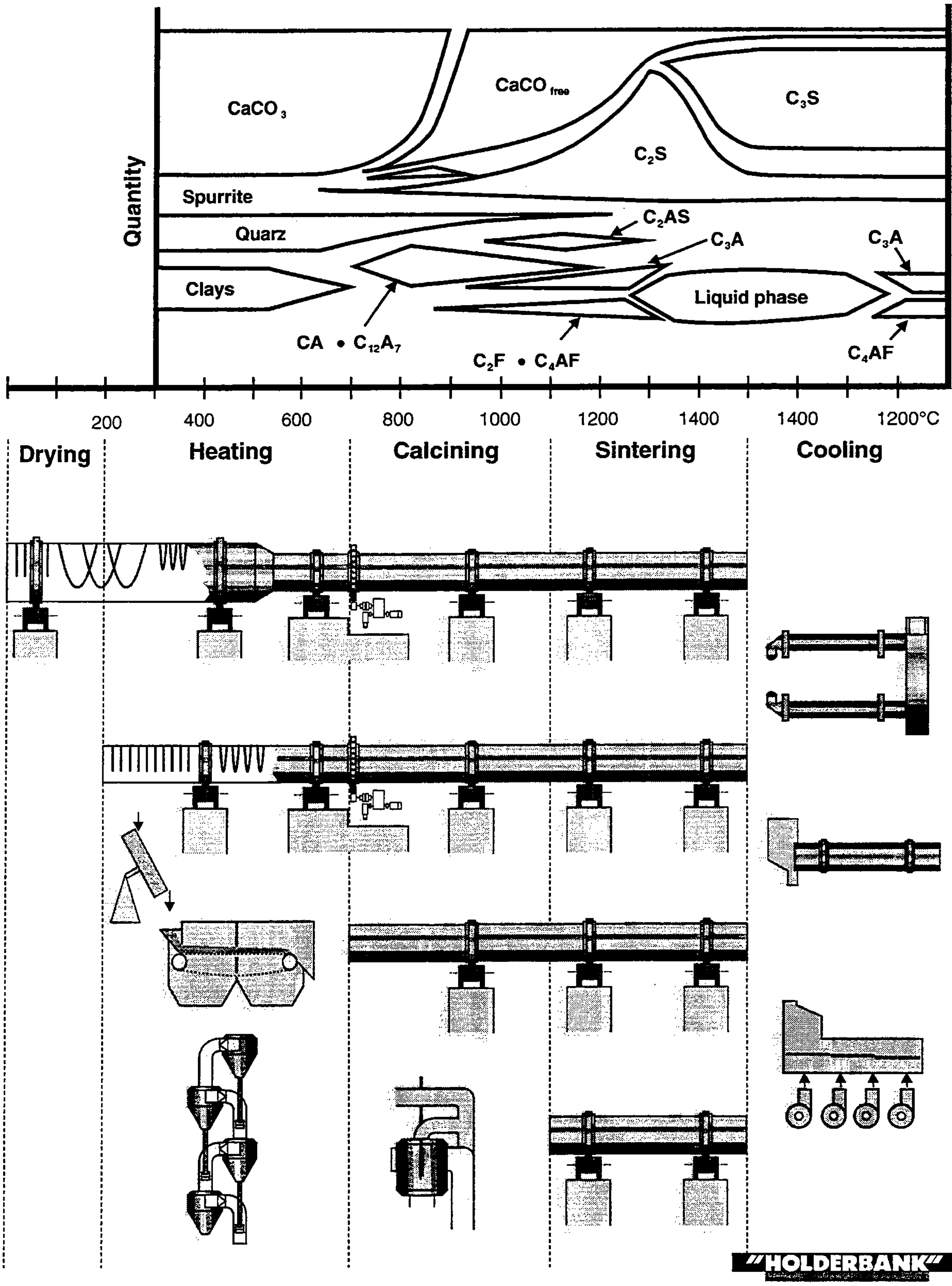
Process and equipment has been developed and improved with the aim at performing these steps forever improved economy, which means

- High availability
- Low heat consumption
- Low power consumption
- Higher unit capacity
- Stable kiln operation
- Good, uniform clinker quality

Table 1 Sequence of Reactions occurring in a Rotary Kiln

Temperature range (°C)	Type of reaction
Heating Up	
20 - 100	Evaporation of free H2O
100 - 300	Loss of physically absorbed water
400 - 900	Removal of structural H2O (H2O and OH groups) from clay minerals
> 500	Structural changes in silicate minerals
600 - 900	Dissociation of carbonates CO2 driven out)
> 800	Formation of belite, intermediate products, aluminate and ferrite
> 1250	Formation of liquid phase (aluminate and ferrite melt)
approx. 1450	Completion of reaction and re-crystallisation of alite and belite
Cooling	
1300 - 1240	Crystallisation of liquid phase into mainly aluminate and ferrite

Heat exchangers in a kiln system



CC-99064.dsf / Kma 22.2.99

2. PROCESS TYPES

2.1 General

The criterion normally used to distinguish the process types is the moisture of the kiln feed material. Four basically different process types for clinker burning can be defined:

Process Type	Feed Material	Cons.	Feed Moisture	Feed System
Dry process	Raw meal	Dry	< 1% H_2O	Mechanic, pneumatic
Semi dry process	Nodules	Moist	≈ 10 ... 12% H_2O	Mechanic, pneumatic
Semi wet process	Filter cake, nodules	Moist	≈ 17 ... 21% H_2O	Mechanic, pneumatic
Wet process	Slurry	Liquid	≈ 25 ... 40% H_2O	Hydraulic

Table 1 gives a general survey of the various rotary kiln systems in operation for industrial clinker production. Shaft kilns, which are still used in China or experimental systems such as sintering grates or fluidised beds, are not considered in the scheme.

We can distinguish two main groups of kiln systems:

a) Long kilns with or without internal heat exchanging installation

b) Short or medium kilns with external preheaters
(e.g. suspension preheaters, grates or external slurry preheaters)

The heat consumption of burning depends strongly on the water content of the kiln feed

This can be illustrated by the typical specific heat consumption: The fuel consumption of wet kilns is nearly twice as high as for modern dry process suspension pre-heater kilns.

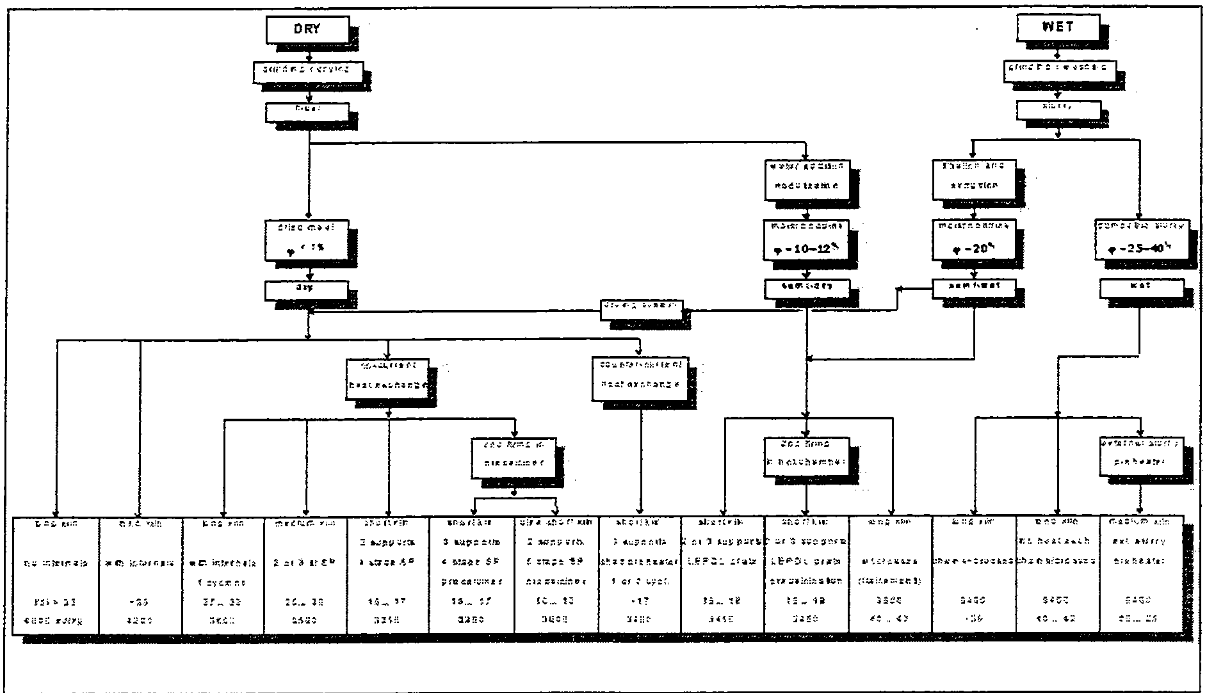
The comparison of the heat economy within each process group (dry or wet) shows clearly:

The more intensive the heat-exchange for drying and preheating, the lower the heat consumption.

Other than based on the feed moisture, kiln systems can be grouped in different ways:

Process Type	wet semi wet semi dry dry	>25% H_2O in feed 17 - 21% H_2O in feed 10 - 12% H_2O in feed < 1% H_2O in feed	Slurry nodules from slurry nodules from meal raw meal
Production Mode	batch+cont. continuous	< 200 t/d 300 t/d – 10'000 t/d	shaft kilns rotary kilns
Heat Consumption		2900 kJ/kg cli (700 kcal/kg cli) > 6000 kJ/kg cli (> 1400 kcal/kg cli)	state of the art system long wet or dry kilns, not optimum operation
Power Consumption		20 to 65 kWh/t cli	kiln feed to clinker cooler

OVERVIEW OF KILN AND PROCESS TYPES



General Overview of Process Types and Rotary Kiln Systems

When the concept for a new plant is developed, not only the present situation but also the possible future developments of all relevant factors must be taken into account.

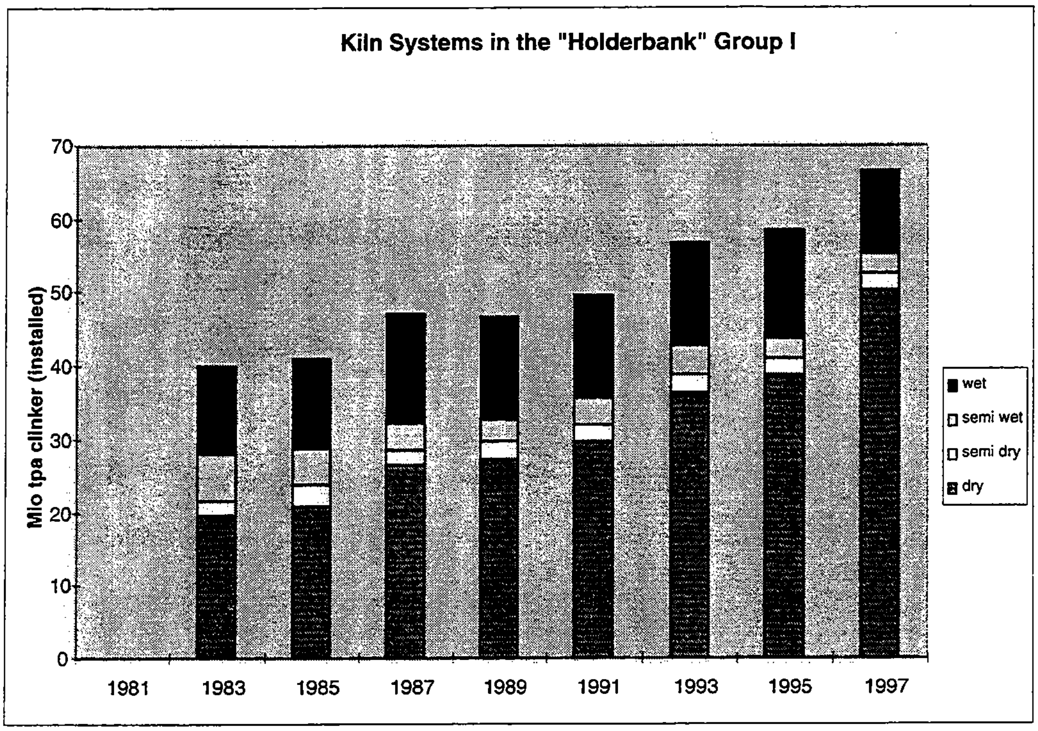
The following main parameters must be considered when selecting the kiln system:

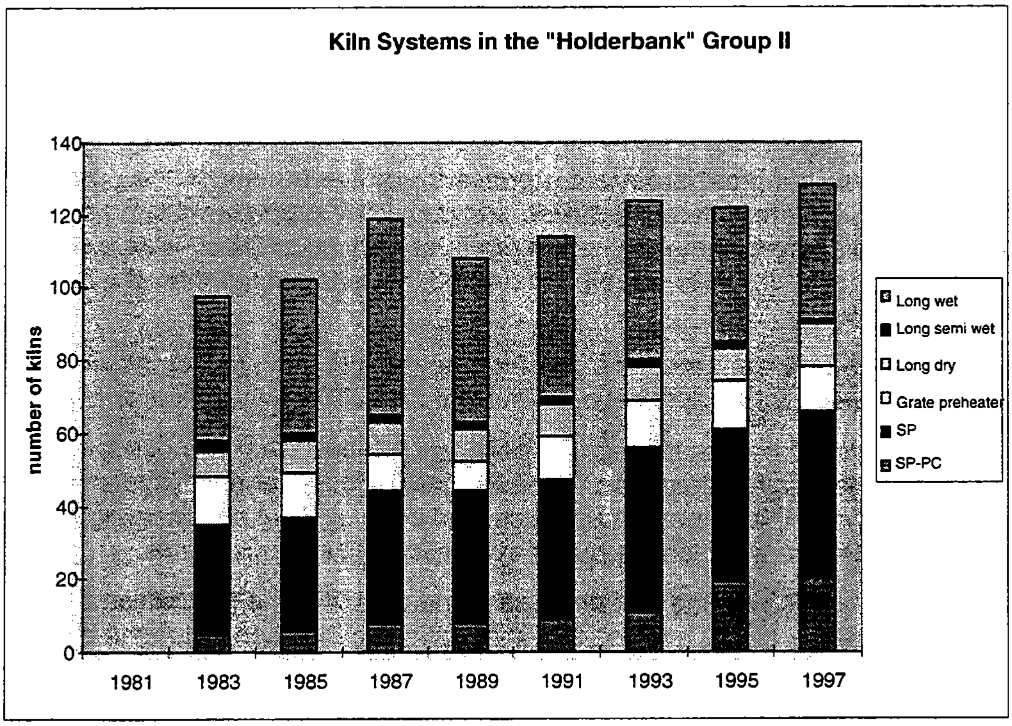
- Raw material:
    - moisture content
    - grindability
    - homogeneity of deposit
    - number of components for raw mix
    - chemical composition (sulphur, chlorides, alkalis, organic compounds etc)
    - filtration properties of slurry (for semi-wet process only)
- Plant installation and operating costs
- Requirements for clinker quality (e.g. low alkali clinker)
- Aspects of environmental protection (emission of dust, SOx, NOx, etc)
- Technical standard of the country

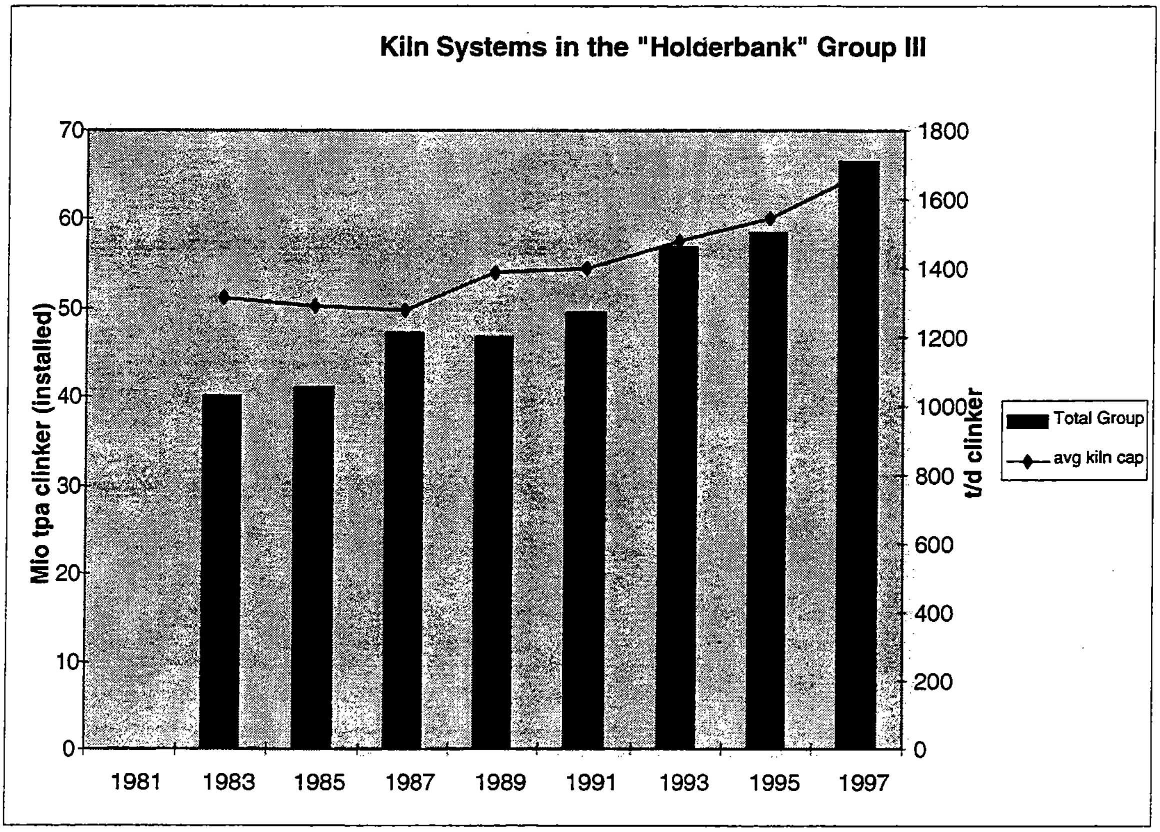
Long wet (and dry) rotary kilns are the oldest and most simple type of installation to produce cement clinker. The pyroprocess takes place in a long rotating tube, which has usually internal equipment to improve heat transfer, and, in wet kilns, to reduce dust loss. Unit capacities of up to 2000 t/d are typically achieved, higher outputs are possible, however, they require kilns of gigantic dimensions.

Today, economy requires plants for 3000 to 10'000 t/d. Therefore new plants are almost always based on the dry process with preheater, pre-calciner and reciprocating grate cooler. The semi wet process for a new plant could be preferred in special cases, e.g. where raw material with a high natural moisture must be used (e.g. quarry below water level).

The three following graphs illustrate the development of the significance of the various processes within the Holderbank group, which can be considered representative of the global situation.


Kiln Systems in the "Holderbank" Group I
Mio tpa clinker (installed)
0
10
20
30
40
50
60
70
1981
1983
1985
1987
1989
1991
1993
1995
1997
wet
semi wet
semi dry
dry


Kiln Systems in the "Holderbank" Group II
number of kilns
0
20
40
60
80
100
120
140
1981
1983
1985
1987
1989
1991
1993
1995
1997
Long wet
Long semi wet
Long dry
Grate preheater
SP
SP-PC



3. WET PROCESS

3.1 General

The wet process was the most important process for clinker burning in the past and almost all plants were wet. Heterogeneous quarries and corrective addition were no problem; stirring of the liquid slurry in the slurry tanks provides very good batch-wise blending. Grinding was done in slurry mills, which consume 30%, less energy than dry ball mills, but at higher lining wear rates.

The disadvantage of the wet process is the high heat consumption. Compared to e.g. a suspension preheater kiln, the difference is more than 2000 kJ/kg clinker or 60 to 70%!

Today, with efficient dry homogenising technology available, the wet process is no longer applied for new plants. Investments as well as operating costs of a wet system are higher than for dry systems of the same output. Technical development allows using more efficient kiln systems even where wet plants would have been built in earlier times.

Another reason for preferring the wet process in the past was the production of low alkali cement (alkali content < 0,6%) and the fact that difficult circulation problems are easier to control in wet kilns. Today secondary firing or efficient bypass installations with precalciner are possibilities to keep these problems under control also in modern kiln systems.

Because of the lower specific gas volume and the shorter rotary part, rotary kiln dimensions as well as gas handling, dedusting and fuel preparation can be designed accordingly smaller. Although new wet kilns are no longer considered for new plants, they still play an important role in the US as well as in many countries of Eastern Europe and Central Asia.

3.2 Long Wet Process Kilns

Long wet kilns have been the most commonly used burning reactors for a very long time, but because of the high water content of the feed, their heat consumption is up to twice as high as for modern dry systems.

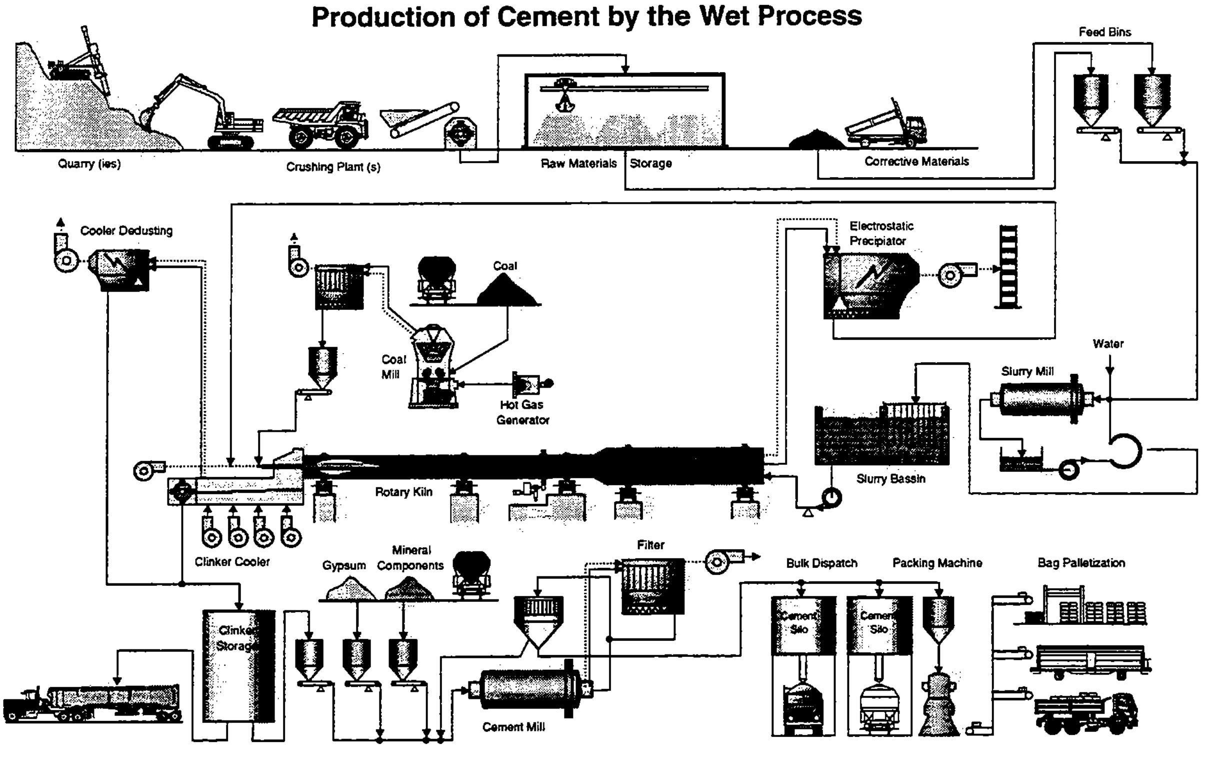
The milled and homogenised raw material is a slurry with a water content of typically 32 to 42% and is pumped to the kiln inlet.

In the first zone heat transfer for the evaporation of water is always increased by means of chain systems (extended surface, higher relative velocities, increase of turbulence). The chain systems should also reduce the dust losses and clean the kiln shell. These internal heat exchanger installations require very special know-how, based to a large degree on experience (see separate paper 'chain systems').

In order to decrease fuel consumption the water content should be kept as low as possible. The limit is normally the pumpability of the slurry. It is basically possible to further reduce the slurry moisture by using slurry thinners. This technology has been successfully applied and will provide an economical advantage if adequate quantities are available at low cost, e.g. as industrial by-product.

Example: Beauport (Canada): 28% feed moisture

Production of Cement by the Wet Process



CC-99057.dsf Kma 17.2.99

Wet kilns are relatively insensitive to circulation problems because the critical temperature ranges are in the rotary part of the kiln (see also 'circulation phenomena').

Low alkali clinker can be produced from high alkali raw material simply by selectively wasting of dust: The highest enriched kiln dust (e.g. from the last precipitator compartment) is removed from the process (i.e. dumped onto a dust pile) as necessary. The rest of the dust can be reintroduced to the kiln by dust scoops or insufflation into the burning zone.

Today, discarding dust creates increasing problems because of restrictive permitting of dust piles.

Note:
Kiln dust cannot just be blended to the slurry because it would react and thicken the slurry.

Typical technical data for long wet kilns with chains:

Heat consumption q	5'000 ... 6'300 kJ/kg cli (1'200 ... 1'500 kcal/kg cli)
Kiln exit gas temperature	150° ... 250°C
System pressure drop	0,5 ... 1,0 kPa
Dust emission in % of clinker production	5 ... 100%

Probably the largest wet process kiln in the world is installed at Holnam's Clarksville plant (Michigan USA). This kiln has a diameter of 7,6 m and a length of 232 m with a daily capacity of about 3'600 t.

3.3 Wet Process Kilns with Slurry Preheaters

External Slurry Preheaters

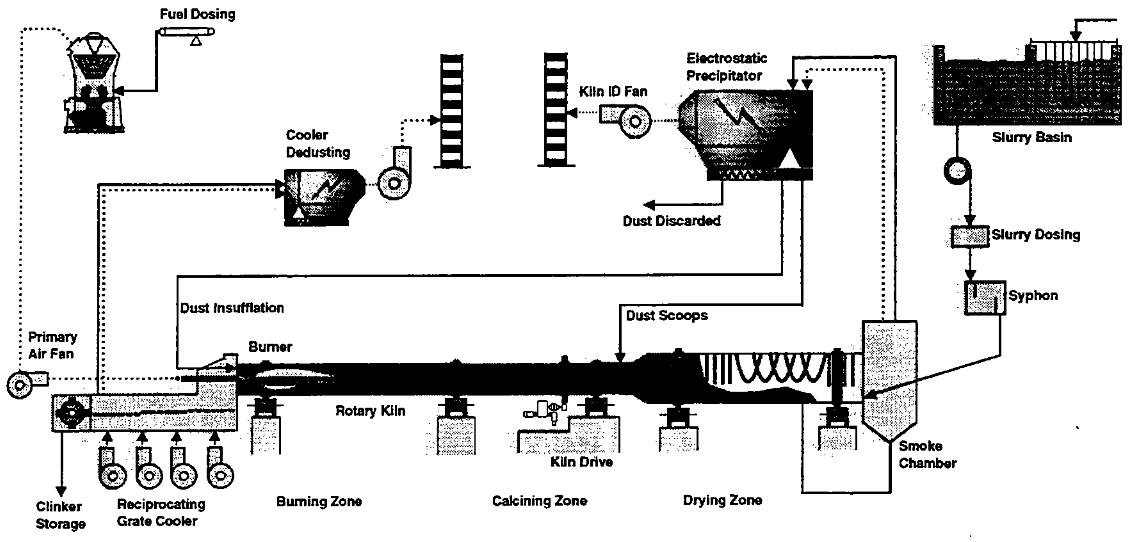
In order to improve the heat exchange between gas and slurry and to reduce the kiln size, external slurry preheaters have been developed by MIAG (Kalzinator) and Krupp (Konzentrator). Both of them are revolving drums with special internal packing. These drums have about the same diameter as the kiln, its length being slightly smaller than the diameter. The capacity of these machines is limited to 800 -1000 t/d and frequently operating problems arise. Very often, external preheaters were large sources of false air.

Internal Slurry Preheaters

F.L. Smidth designed a slurry pre-heater system integrated into the kiln compartment, which should avoid the disadvantage of external slurry preheaters. In practice, this construction turned out to be very sensitive to clogging.

A better system developed by Fives Cail Babcock is installed in the three kilns at Obourg. Lifting buckets and chain curtains produce a slurry curtain that keeps back a high amount of dust and improves heat exchange.

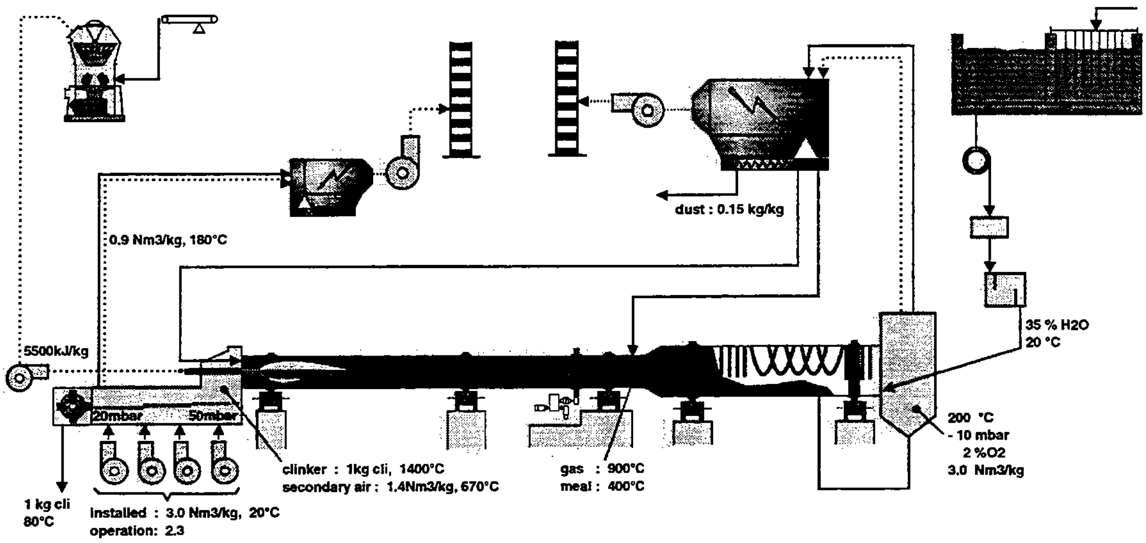
Wet process kiln



"HOLDERBANK"
Process Technology

CC-99062.dsf / Kma 17.2.99

Wet process kiln



Capacity	:	100	- 3600	t/d	Kiln feed	:	slurry, 28	-	43	% H2O
Diameter	:	2.5	- 7.5	m	Kiln circumferential speed	:	10	-	20	m/min
Length	:	40	- 230	m	Kiln slope	:	2.5	-	4	%
Length/Diameter	:	30	- 38		Total chain weight	:	10	-	15	% rel. to capacity
Kiln load (inside lining)	:	0.4	- 0.8	t/m3d	Dust losses	:	0.05	-	0.25	kg/kg cli
BZ load (inside lining)	:	40	- 100	t/m2d	Spec.heat consumption	:	5000	-	7000	kJ/kg cli

CC-99072.dsf / Kma 17.2.99

4. SEMI WET PROCESS

4.1 General

A process is considered semi-wet if the kiln feed is produced from wet slurry. A mechanical water extraction process reduces the water content of the kiln feed to 17 to 21%. A number of filter presses operating batch-wise are commonly used, but also continuous filter band presses or similar equipment would be possible.

4.2 Semi Wet Process Long Kilns

Principally, long kilns with heat exchanger crosses can be fed with slurry, filter cakes or dry meal. Feeding filter cakes is a straightforward and simple solution and is used by Italcementi in some cases.

4.3 Semi Wet Grate Preheater Kilns

Most of the semi-wet systems use a grate preheater kiln fed with filter cakes.

A grate preheater system includes a short rotary kiln (similar to a four stage preheater kiln) where only calcining and sintering take place. For drying, preheating and partial calcining, a travelling grate is installed in front of the kiln, where heat of the kiln exhaust gases is used.

For the semi-wet grate kiln, the slurry must be prepared in a special way so it can be fed to a travelling grate:

The pumpable slurry as starting material is fed to filter presses where the moisture content is reduced to approx. 20% applying a filtration pressure of 15 to 20 bar. In a special type of extruder (Siebkneter), the filter cakes are converted into cylindrical nodules (diameter 15 ... 20 mm, length 30 ... 50 mm) and then fed to the preheater-grate. The economy of this way of preparation depends strongly on the filtration properties of the slurry.

Operating and performance data are similar to the semi-dry grate preheater systems described under 5.2.

Characteristic data of a semi-wet grate pre-heater system:

Feed Nodules made from	Slurry Filter Cake
Moisture Content of the Feed	10 ... 12%
Heat consumption q	3770 kJ/kg cli (□ 900 kcal/kg cli)
Exit gas temperature after grate	100° ... 120°C
System pressure drop	2,6 kPa

Example of a semi-wet LEPOL kiln:

AB's kiln 10 at the Lägerdorf plant (Germany)

Maximum kiln capacity: *3'600 t/d*

Kiln dimensions: *ϕ 6.0/5.6 m x 90 m*

Grate dimensions: *5.6 x 61.7 m*

Secondary firing with Fullers earth (special)

(Shut down; replaced by semi wet precalciner kiln in 1996)

Production of Cement by the Semi-Wet Process

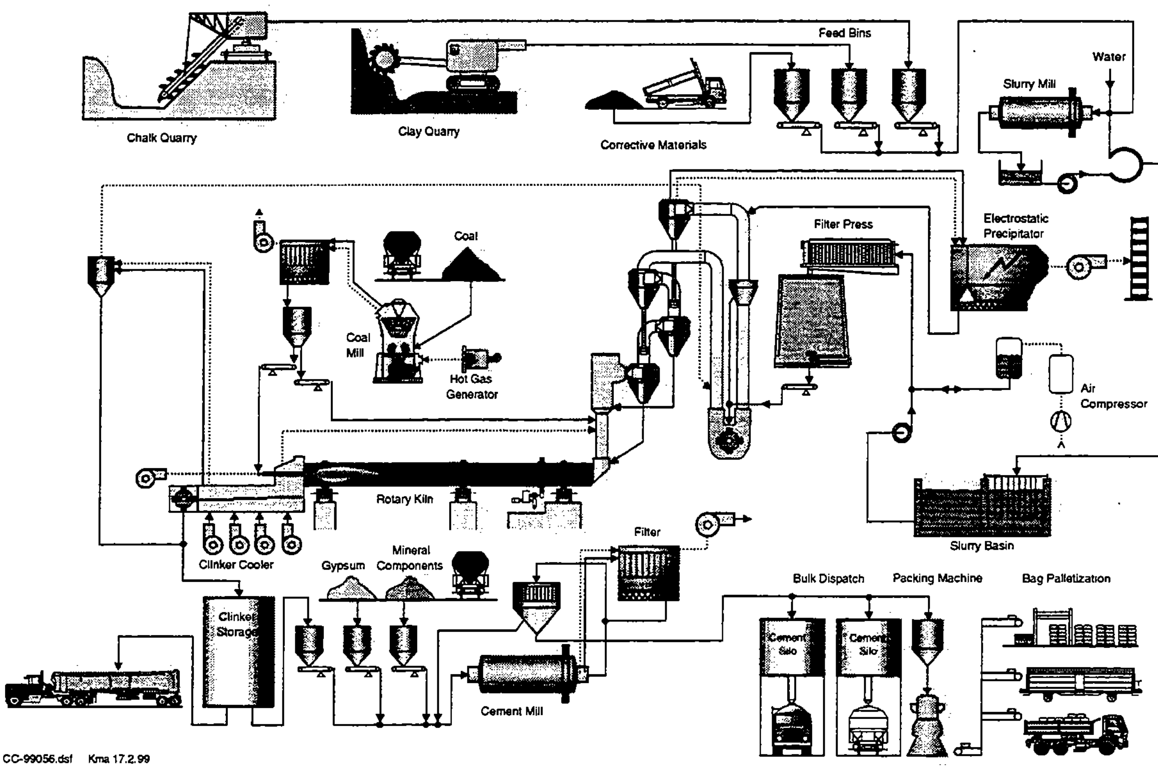


Figure 4

4.4 Semi-Wet Suspension Pre-heater Kiln

The suspension preheater kiln is normally fed with dry meal (details see separate paper). However, there are some rare cases where suspension preheater kilns are fed with nodules prepared from slurry. These nodules should not be too strong because they must be cracked by thermal shock or abrasion before being fed to the kiln system via top stage of the pre-heater.

A two-stage pre-heater kiln operated with semi-wet nodules was e.g. the Liesberg plant. There, the nodules were cracked in a vertical dryer before being fed to the preheater.

The first modern kiln system using this principle has been built in the late 1980's by FLS in Aalborg Cement's RORDAL plant. It is a three stage two string kiln system with precalciner for a capacity of 4000 t/d. The high operating cost of the filter presses has been avoided by directly injecting the slurry into a drier-crusher followed by a vertical drier. The semi-wet process was selected because the raw material (chalk) is mined under water and has very high natural moisture.

From the "Holderbank" group:

Example of a semi-wet pre-heater/pre-calciner kiln:

AB's kiln 11 at the Lägerdorf plant (Germany)

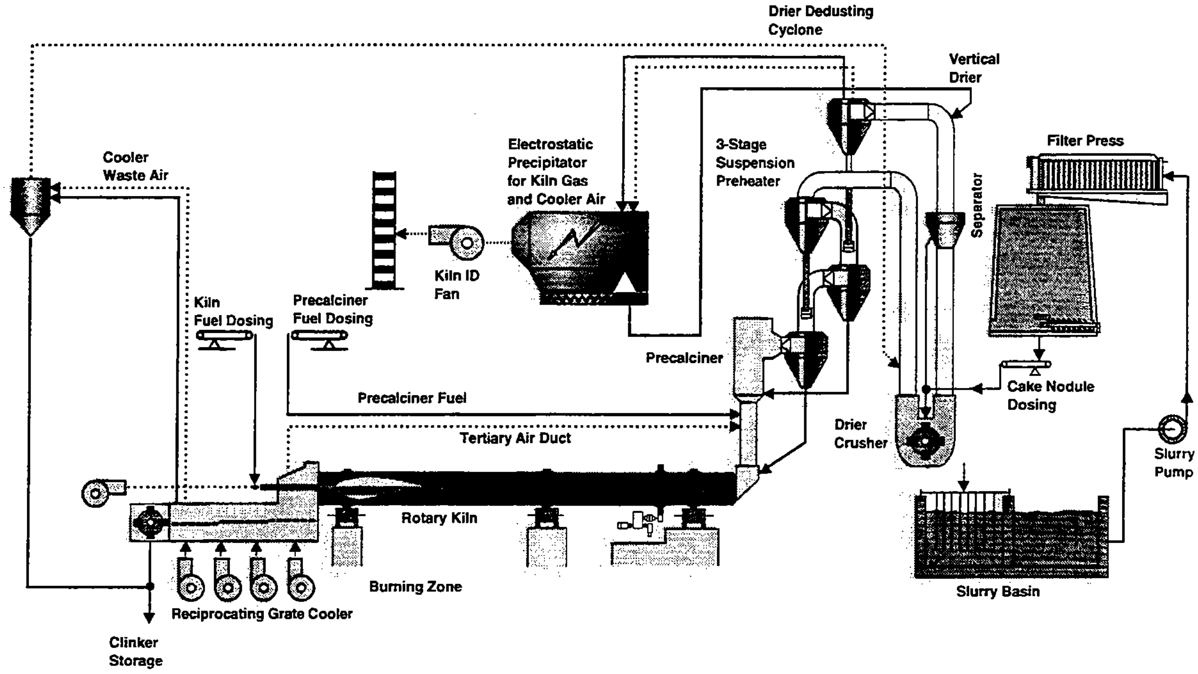
Maximum kiln capacity:	*4'500 t/d at 3900 kJ/kg*
Kiln dimensions:	*ϕ 4.8 x 65 m; 2 supports, gearless friction drive*
Preheater:	*3 stages, 2 strings*

Utilisation of various alternative fuels in both firings

Supplied by Polysius; start-up: 1996

Filter cakes produced in already existing filter-presses

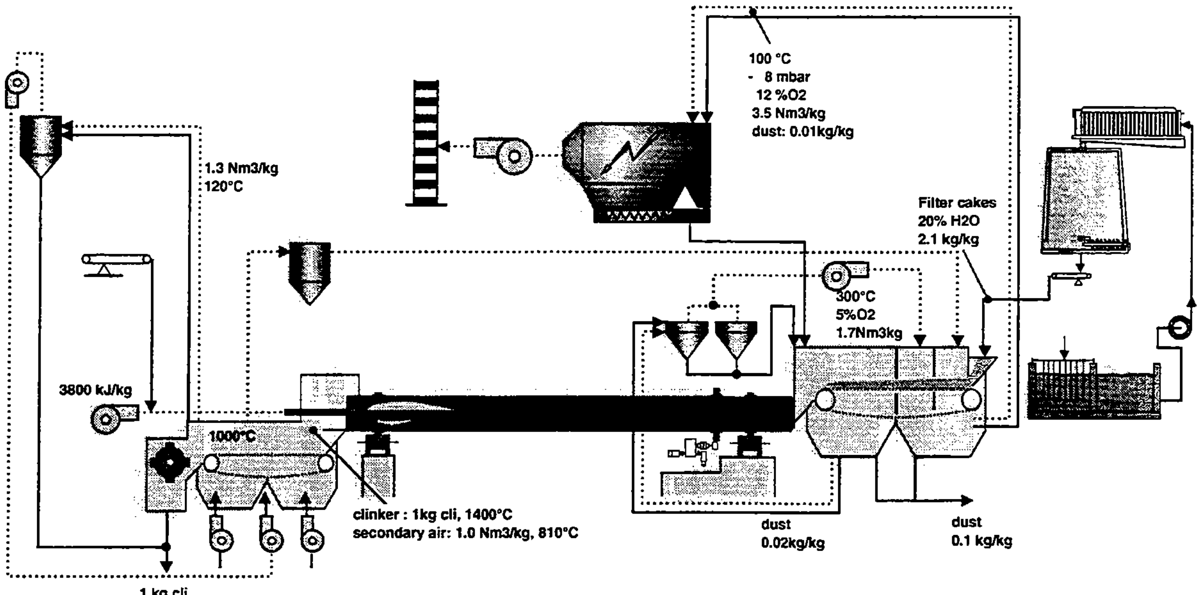
Semi wet process kiln (with 3-stage SP and PC)



"HOLDERBANK" Process Technology

CC-99061.dsf / Kma 17.2.99

Semi wet process kiln (with grate preheater "LEPOL")



Capacity	:	300	- 3000	t/d
Diameter	:	3	- 5.6	m
Length	:	45	- 90	m
Length/Diameter	:	11	- 16	
Kiln load (inside lining)	:	1.5	- 2.2	t/m3d
BZ load (inside lining)	:	80	- 150	t/m2d
Grate load	:	8	- 10	t/m2d

Kiln feed	:	filter cakes,	18	-	23	% H2O
Kiln speed	:		1	-	2	rpm
Kiln slope	:		3	-	3.5	%
Spec.heat consumption	:		3600	-	4500	kJ/kg cli

CC-99071.dsf / Kma 17.2.99

5. SEMI DRY PROCESS

The semi-dry process is characterised by the fact that kiln feed nodules are made from dry raw meal. Water is added in order to produce nodules with 10 - 12% moisture.

5.1 Semi-Dry Process Long Kilns

There are long kilns with heat exchanger crosses fed with nodules. This system was applied by Italcementi and looks very similar to an installation for semi-wet feed material.

5.2 Semi-Dry Process Grate Pre-heater Kilns

The grate preheater kiln is by far the most popular semi-dry system.

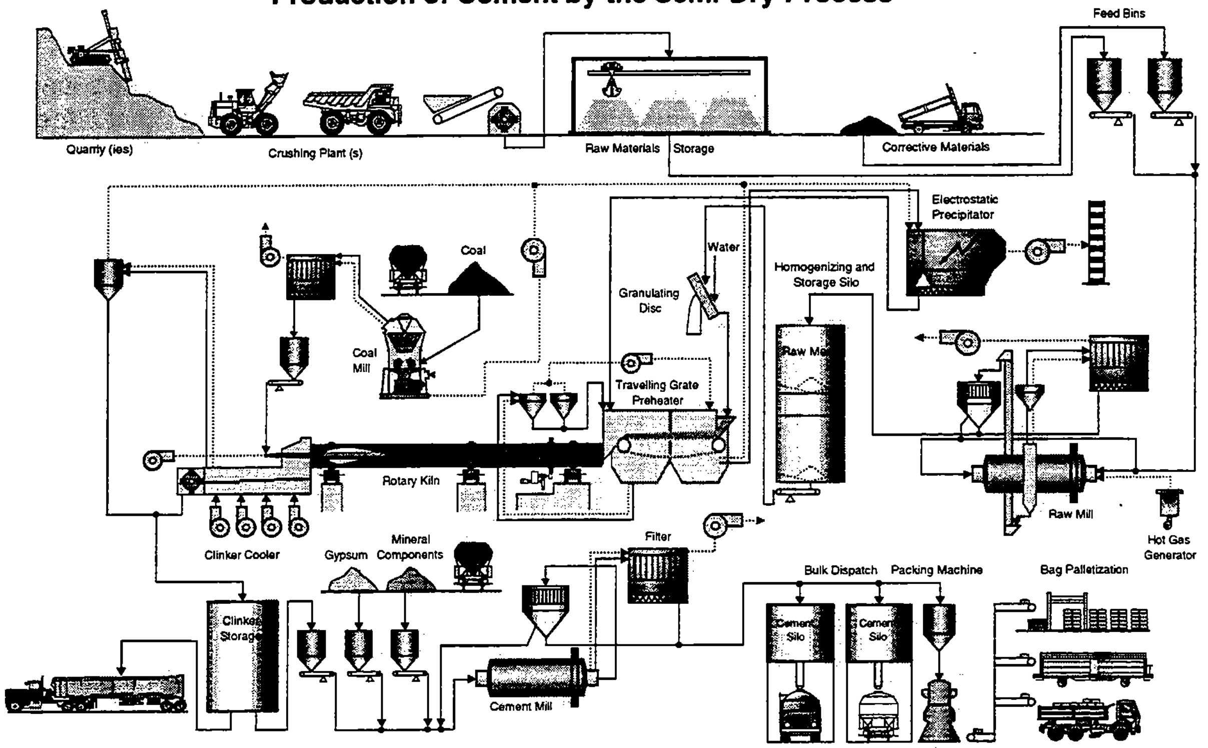
The principle of the grate preheater system for the semi-dry process is identical to the one used for the semi-wet process. What is different is the feed preparation:

The dry raw material is mixed with water (10 ... 12%) and nodulised in a drum or preferably on a rotating plate (pan noduliser). This system can be used only for raw materials containing plastic components enabling the formation of nodules that are resistant against thermal shock and abrasion. The main factor influencing plasticity is the mineralogical composition, especially the presence of montmorillonite.

On the grate, heat exchange from the gas to the nodules forming a fixed bed layer of approx. 20 cm thickness is excellent. In some grate preheaters, precalcination is done successfully, often using even waste fuels (such as Fullers earth, acid sludge, waste lubricating oils etc.) utilising secondary firing.

The only successfully working travelling grate pre-heater was available from Polysius and became known under the name LEPOL system (American licensee: Allis-Chalmers, ACL system).

Production of Cement by the Semi-Dry Process



CC-99055.dsf Kma 17.2.99

This principle sketch shows a LEPOL kiln fed with nodules made out of dry raw meal. LEPOL kilns built after 1945 are equipped with two-pass grates; i.e. the exhaust gas is led twice through the nodule bed from top to bottom:

The hot kiln gas passes first through a bed of dry and preheated nodules and subsequently, after an intermediary dedusting once again trough a layer of moist incoming nodules. It is believed that the nodules survive throughout the process resulting in a clinker with very uniform size.

Furthermore, dust loads in the kiln atmosphere and dust emission out of the system are low. The nodules on the grate let only pass the fine dust while the coarse particles are retained.

In cases of increased trace compound concentrations (especially alkali) in the raw material, the fine dust separated in the electrostatic precipitator is largely enriched with them. Only a small amount of dust has to be discarded to reduce the balance of these compounds in the kiln system. This effect makes the LEPOL kiln quite suitable to produce a low alkali clinker with rather low heat consumption. For this reason, it has been chosen in many cases, particularly in the USA.

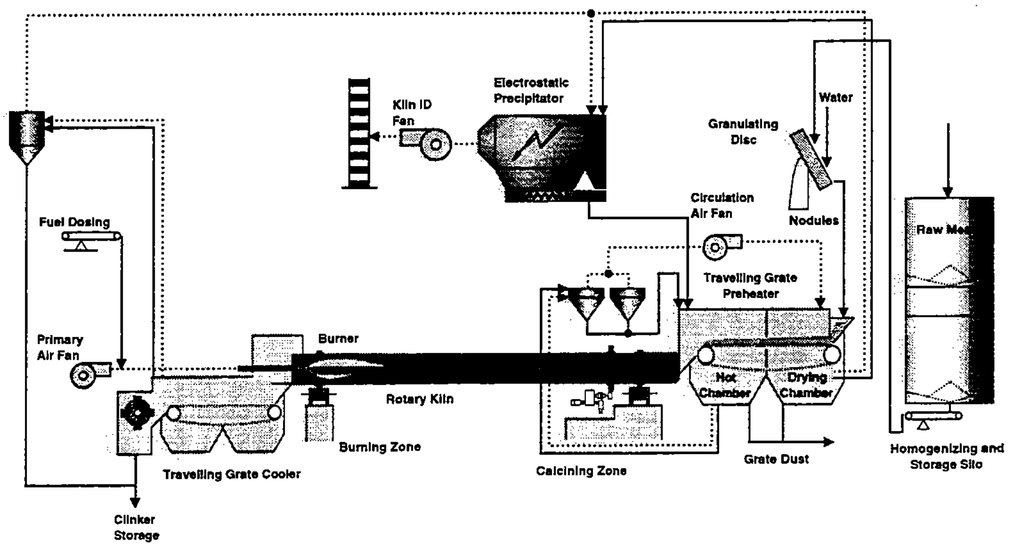
The following limits and disadvantages have to be considered:

- Only raw materials with good plastic properties can be used
  (semi-wet: filter cake nodules -> good filtration properties are required)
- The grate chain is subject to wear.
- Uneven temperature distribution across the grate can cause difficulties.
- Additional theoretical heat consumption due to the water content of the feed (partially compensated by a low exit gas temperature).
- Exhaust gases cannot be used in drying and grinding systems.

Characteristic data of a semi-dry grate pre-heater systems:

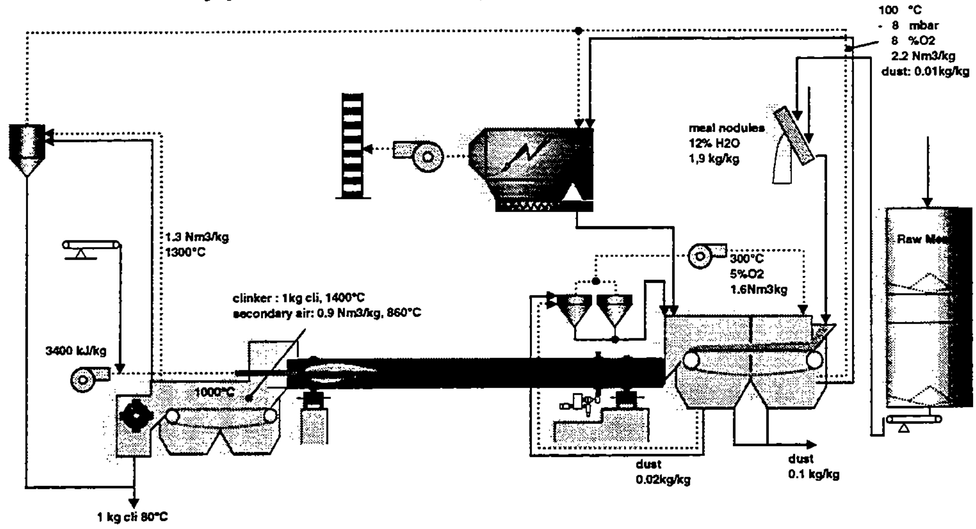
Feed nodules made from	dry raw meal
Moisture content of the feed nodules	10 ... 12%
Specific heat consumption q	3450 kJ/kg cli (= 820 kcal/kg cli)
Exit gas temperature after grate	100 ... 120°C
System pressure drop	2.6 kPa

Semi dry process kiln (with grate preheater "LEPOL")



CC-99060.dsf / Kma 17.2.99

Semi dry process kiln (with grate preheater "LEPOL")



Capacity	:	300	- 2000	t/d
Diameter	:	3	- 4.8	m
Length	:	35	- 80	m
Length/Diameter	:	11	- 16	
Kiln load (inside lining)	:	1.5	- 2.2	t/m3d
BZ load (inside lining)	:	80	- 150	t/m2d
Grate load	:	80	- 12	t/m2d

Kiln feed	:	meal nodules,	11	- 14	% H2O
Kiln speed	:		1	- 20	rpm
Kiln slope	:		3	- 4	%
Spec.heat consumption	:		3200	- 3600	kJ/kg cli

CC-99070.dsf / Kma 17.2.99

6. DRY PROCESS

6.1 Long Dry Kilns

Without internal heat exchange equipment

The simplest kind of dry process installation is the long dry kiln without any internal heat exchange equipment (empty tube). With a heat consumption of 5100 kJ/kg cli (1200 kcal/kg cli) or about 90% of the wet process it must be considered very uneconomical. Advantages might be its simplicity and insensitivity to heavy circulation problems.

This kiln type is suitable to be used in combination with waste heat recovery steam boilers for power generation. In that case, the waste heat contained in the hot kiln exhaust gases is further used to produce valuable energy.

Characteristic kiln data:

Heat consumption q	4500 ... 6000 kJ/kg cli	(1075 ... 1430 kcal/kg cli)
Kiln gas exit temperature	450° ... 500°C	
System pressure drop	0,5 ... 1,0 kPa	

With internal heat exchange equipment

Long dry kilns with internal heat exchange equipment (chains or crosses from steel or ceramic material) represent a more economical solution. Heat consumption of 4200 kJ/kg or even less can be achieved. Other typical operating figures are contained in annex 10.

Characteristic kiln data:

Heat consumption q	3800 ... 4500 kJ/kg cli	(910 ... 1075 kcal/kg cli)
Kiln gas exit temperature	400° ... 450°C	
System pressure drop	1,0 ... 1,5 kPa	

6.2 Raw Meal Suspension Preheater Kilns

6.2.1 General

During the last thirty years, the suspension preheater kiln became the dominant clinker manufacturing system. This system is fed by dry raw meal that is preferably prepared in a grinding and drying plant, using the kiln waste gases as a drying medium. This ground and dried raw meal is homogenised and then fed to the preheater where it is suspended in the kiln gas flow, where an extremely effective heat transfer takes place. More information is contained in the special section "Suspension Preheaters".

6.2.2 One and two Stage Cyclone Pre-heater Kilns

Characteristic kiln data:

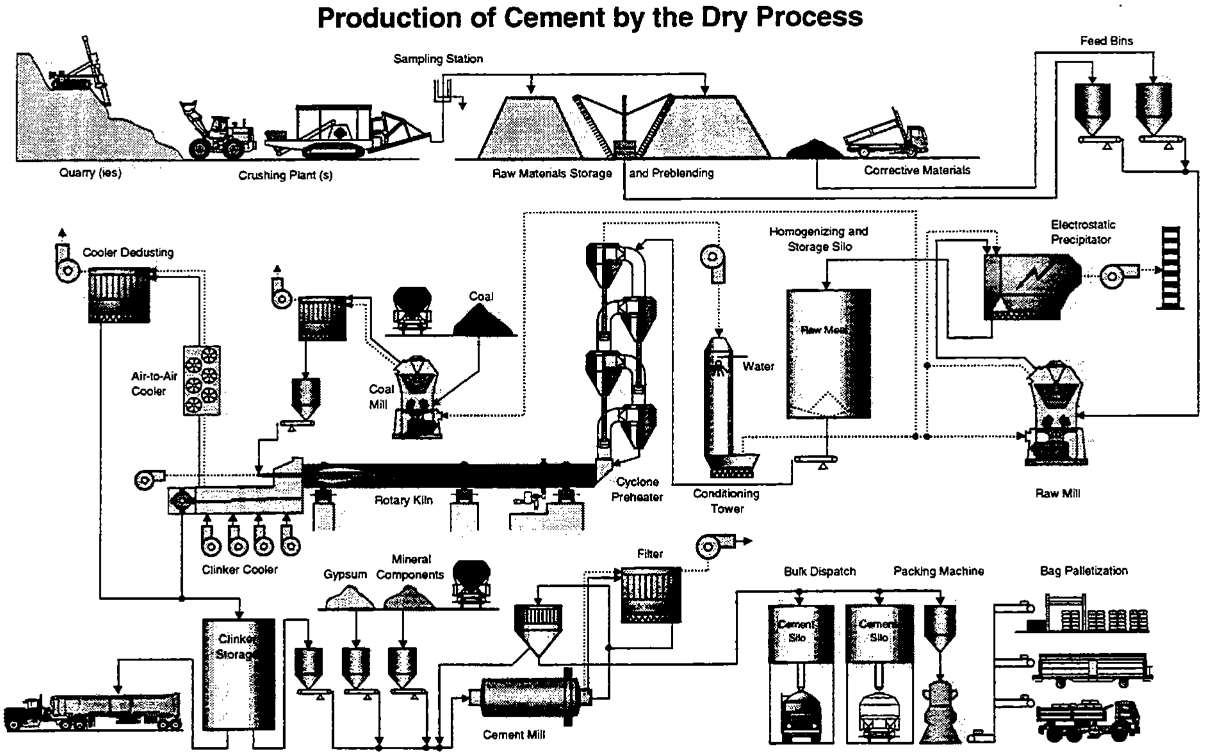
one stage:

Heat consumption q	3750 ... 4000 kJ/kg cli	(900 ... 950 kcal/kg cli)
Kiln gas exit temperature	400° ... 500°C	
System pressure drop	1,5 ... 2,5 kPa	

two stages:

Heat consumption q	3500 ... 3750 kJ/kg cli	(850 ... 900 kcal/kg cli)
Kiln gas exit temperature	400° ... 450°C	
System pressure drop	1,5 ... 2,5 kPa	

Production of Cement by the Dry Process



CC-99054.dsf Kma 17.2.99

6.2.3 Four Stage Cyclone Pre-heater Kilns

Until the mid 1980s, this arrangement belong to the systems with the lowest fuel consumption. It was offered in several configurations with capacities up to 4500 t/d, most of them being combinations of single or twin cyclone stages.

The kiln exit gas includes still enough heat to dry raw material up to moisture content of 8% if the mill is running during all the kiln operation time. From this point of view, the remaining relatively high exit gas temperature cannot be considered fully as a loss, because it can substitute an auxiliary firing for raw material drying.

The preheater system is installed in a steel or concrete tower with a height of about 60 to 120 m (6 stages) above the kiln inlet, depending on capacity and concept.

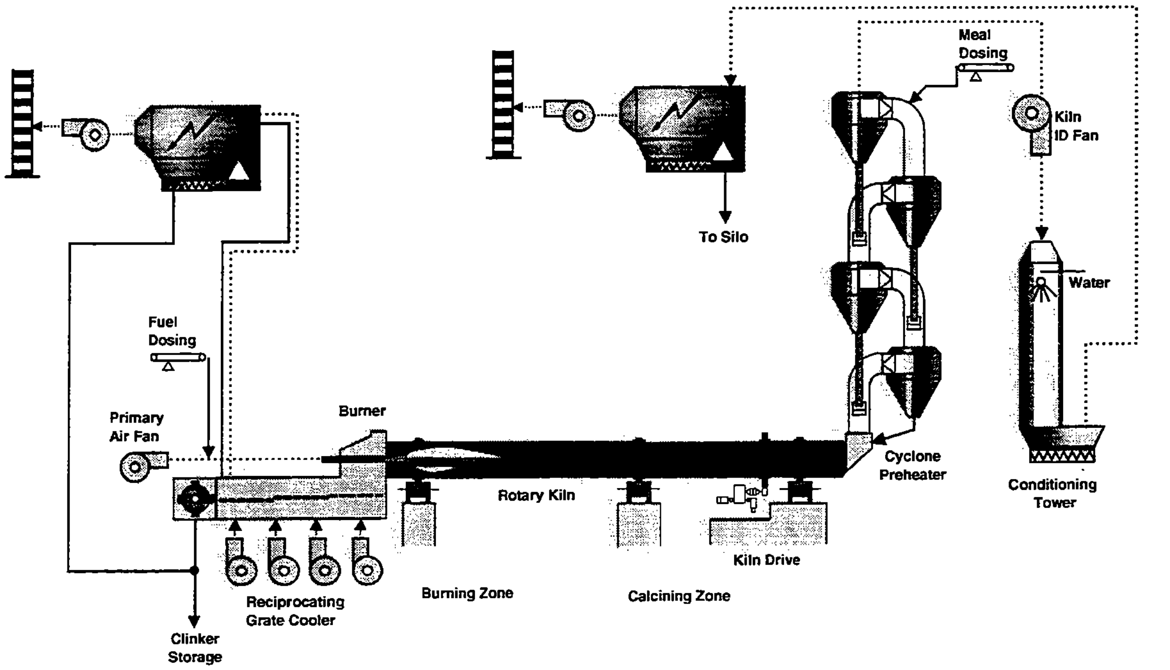
The four to six stages preheater is most susceptible to circulation problems at presence of excessive concentration of circulation compounds causing clogging problems in the pre-heater system.

The sketch shows a conventional four stage cyclone preheater system. In the 1970's, production lines with more than approx. 2000 t/d had to be built with two parallel preheater strings. Today, one-string installations are possible for up to 4000 t/d.

Characteristic operating figures of 4-stage pre-heater kilns:

Heat consumption q	
small units	3350 ... 3550 kJ/kg cli (= 800 ... 850 kcal/kg cli)
large units	3150 ... 3350 kJ/kg cli (= 750 ... 800 kcal/kg cli)
kiln exit gas temperature	320° ... 350°C
kiln exit gas volume	approx. 1,5 Nm3/kg cli
System pressure drop	4 ... 6 kPa
Dust loss relative to clinker	8 ... 15%
Transition chamber	
kiln gas temperature	approx. 1100°C
Material temperature	approx. 800°C

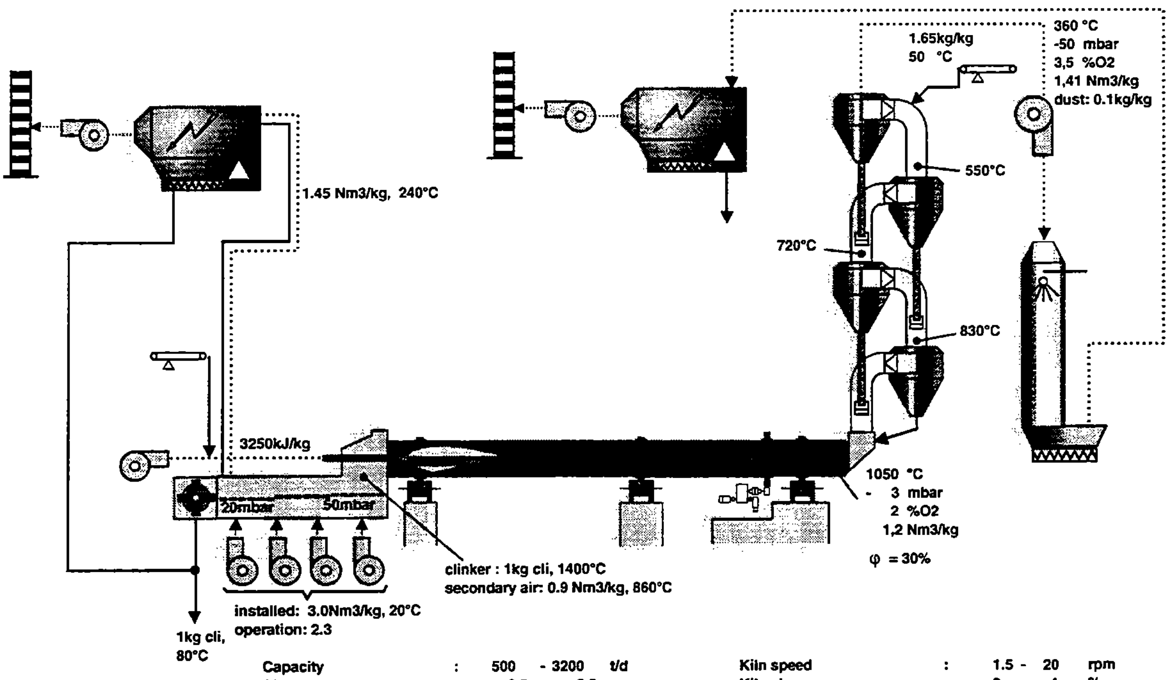
Dry process kiln (with 4-stage SP)



CC-99063.dsf / Kma 17.2.99

"HOLDERBANK"
Process Technology

Dry process kiln (with 4-stage SP)



Capacity	:	500 - 3200 t/d		Kiln speed	:	1.5 - 20	rpm
Diameter	:	3.5 - 5.5 m		Kiln slope	:	3 - 4	%
Length	:	50 - 90 m		Spec.heat consumption	:	3150 - 3500	kJ/kg cli
Length/Diameter	:	14 - 16					
Kiln load (inside lining)	:	1.5 - 2.2 t/m3d					
BZ load (inside lining)	:	100 - 180 t/m2d					

CC-99073.dsf / Kma 17.2.99

6.2.4 Precalciner Kilns

For larger production capacities, a larger portion of the pyroprocess had to be relocated out of the rotary kiln in order to maintain reasonable kiln diameters without excessive thermal load of the burning zone.

The process of dissociation of CO_2 (calcination) is suitable to take place in a static reactor outside of the rotary kiln. Of the total heat consumption, 60 to 65% are required to achieve about 90% of calcination. 100% calcination must be avoided because clogging problems will seriously disturb kiln operation (beginning of clinker formation).

The development of this reactor started with a secondary firing in the kiln riser duct sufficient for 35 to 40% calcination of the meal, combustion air still pulled through the kiln tube (=air through). It was therefore referred to as precalciner (PC) type AT. Only when hot cooler air (= tertiary air) for the PC fuel (= secondary fuel) was taken to the calciner in a separate duct, the so called tertiary air duct, the full benefit of this technology could be used. Today, only this type called PC-AS (=air separate) is considered a real precalciner. The elements of a precalciner kiln system are explained in the sketch.

The strongest boost of calciner development was in the seventies in Japan, initiated by the demand for very large units exceeding the potential of conventional kilns with suspension preheaters. Only precalciner technology makes today's largest units of 10'000 t/d possible.

Two process alternatives of precalciner are used:

- in-line calciner (calciner installed in kiln gas flow)
- separate-line calciner (calciner not passed by kiln gases)

More details on calciner technology are contained in a separate section.

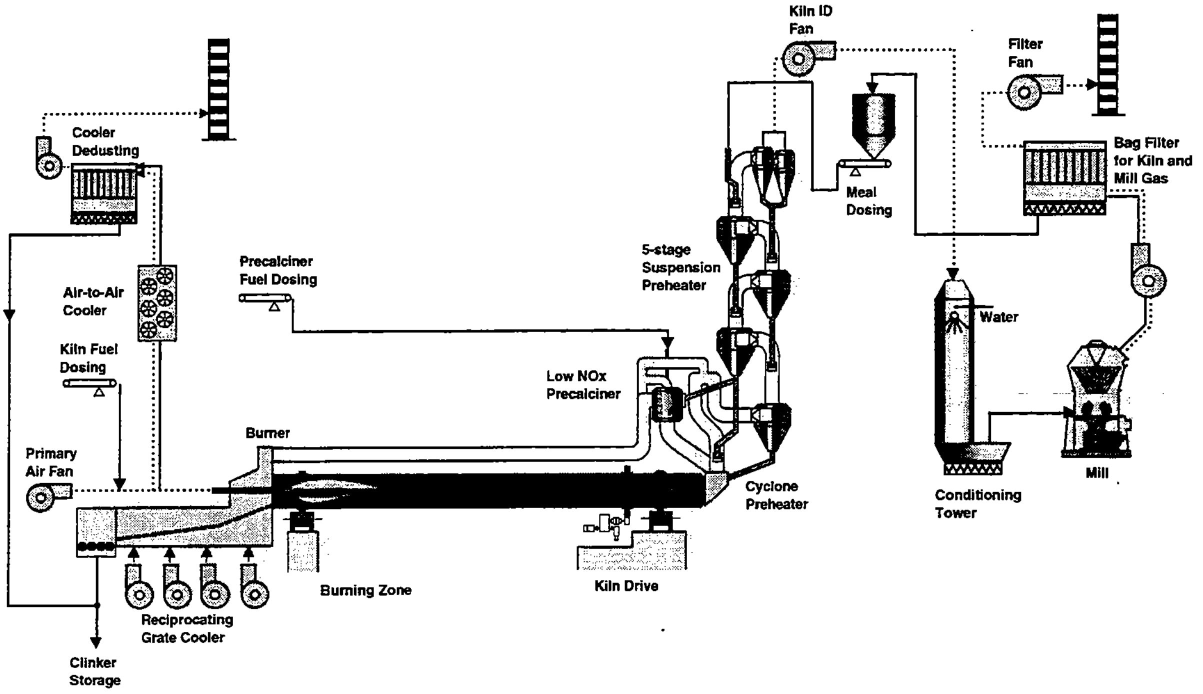
The operating data are very close to the ones of the corresponding preheater kiln system. In-line calciners have a tendency to higher gas exit temperature and system pressure drop; however, modern units are equipped with 5 or 6 preheater stages to compensate for this.

Characteristic operating data of 4 to 6 stage precalciner kilns:

Heat consumption q	
small units, 4 stage SP	3350 ... 3550 kJ/kg cli (= 800 ... 850 kcal/kg cli)
large units, 5 stage SP	2900 ... 3200 kJ/kg cli (= 700 ... 800 kcal/kg cli)
SP exit gas temp. 6 to 4 st. SP	290° ... 370°C
SP exit gas volume	approx. 1.3 to 1.5 Nm3/kg cli
System pressure drop	4 ... 6 kPa
Dust loss relative to clinker	8 ... 15%
Transition chamber:	
kiln gas temperature	approx. 1100°C
Material temperature	approx. 800°C

More data of precalciner kiln systems are shown in the section "Precalciners".

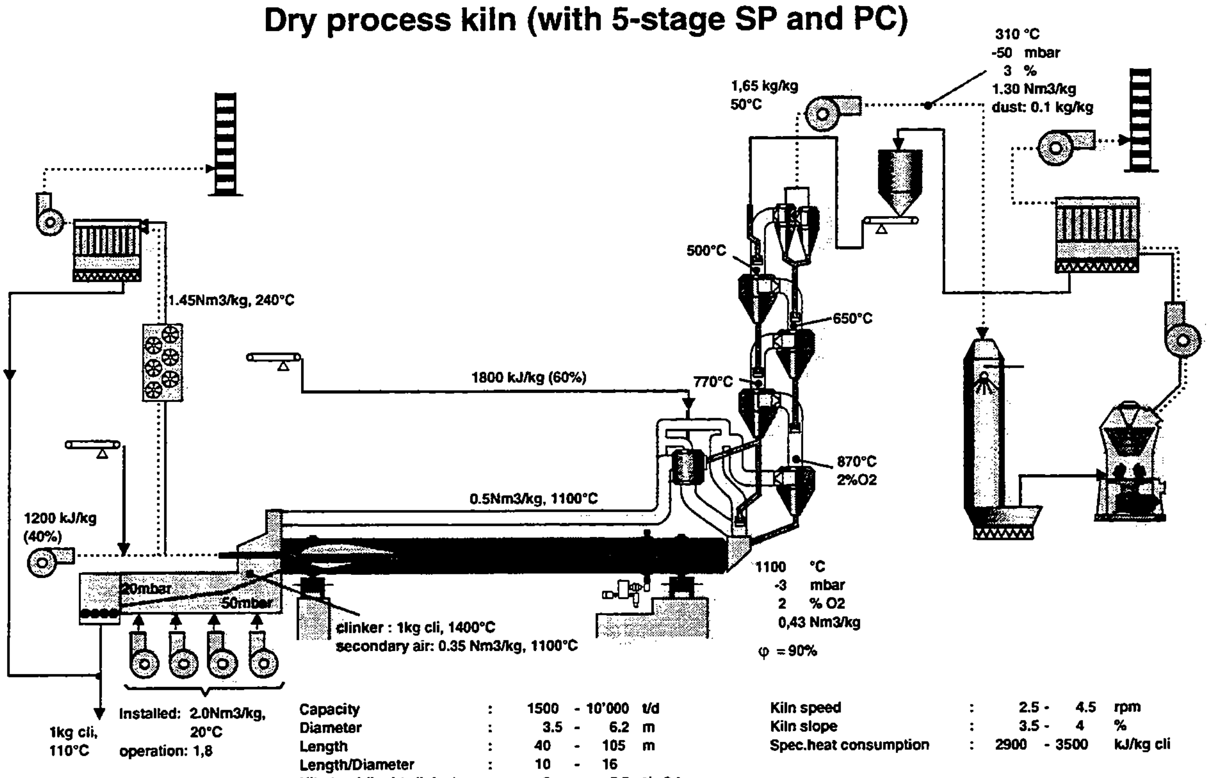
Dry process kiln (with 5-stage SP and PC)



CC-99069.dsf / Kma 17.2.99

"HOLDERBANK" Process Technology

Dry process kiln (with 5-stage SP and PC)



Capacity	:	1500 - 10'000	t/d
Diameter	:	3.5 - 6.2	m
Length	:	40 - 105	m
Length/Diameter	:	10 - 16	
Kiln load (inside lining)	:	3 - 5.5	t/m3d
BZ load (inside lining)	:	185 - 350	t/m2d

Kiln speed	:	2.5 - 4.5	rpm
Kiln slope	:	3.5 - 4	%
Spec.heat consumption	:	2900 - 3500	kJ/kg cli

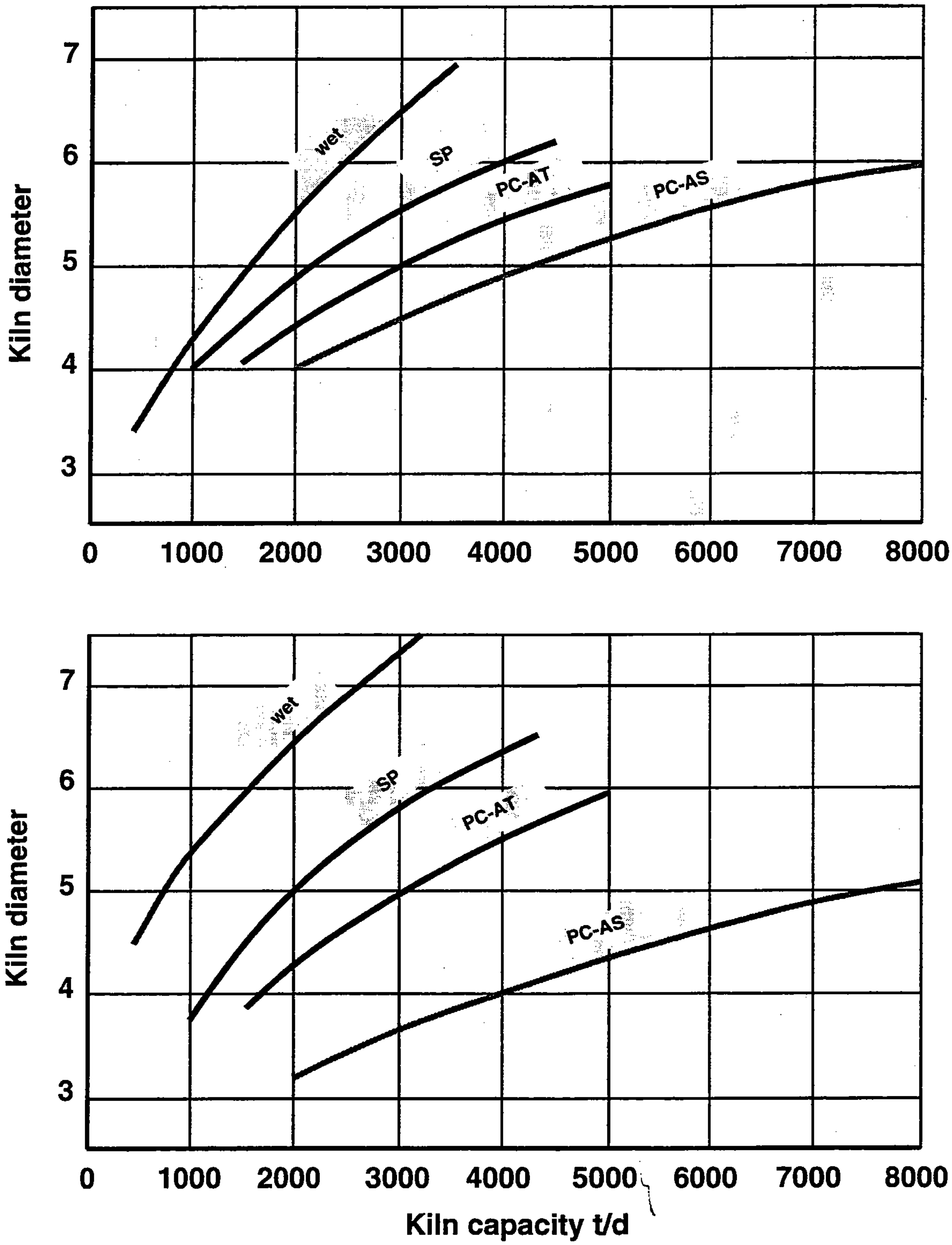
CC-99079.dsf / Kma 17.2.99

HEAT BALANCE

WET / SEMI-DRY / 4-ST. PREHEATER / 5-ST. PREHEATER-PRECALCINER

		WET PROCESS		SEMI-DRY LEPOL		4-STAGE SP		6-STAGE SP-PC	
Input		kJ/kg cli	%	kJ/kg cli	%	kJ/kg cli	%	kJ/kg cli	%
Fuel kiln	combustion	**5560**	96.7%	**3343**	97.6%	**3150**	97.7%	**1180**	39.2%
	sensible heat	25	0.4%	15	0.4%	13	0.4%	5	0.2%
Fuel PC	combustion	0	0.0%	0	0.0%	0	0.0%	**1775**	58.9%
	sensible heat	0	0.0%	0	0.0%	0	0.0%	8	0.3%
Kiln feed	sensible heat	25	0.4%	30	0.9%	54	1.7%	45	1.5%
	sensible heat of water	73	1.3%	17	0.5%	0	0.0%	0	0.0%
Insufflated air (PA, cooler)		67	1.2%	20	0.6%	6	0.2%	0	0.0%
Total inputs		**5750**	100%	**3425**	100%	**3223**	100%	**3013**	100%

Output	kJ/kg cli	%	kJ/kg cli	%	kJ/kg cli	%	kJ/kg cli	%
Heat of formation	1750	30.4%	1750	51.1%	1750	54.3%	1750	58.1%
Water evaporation	2370	41.2%	506	14.8%	13	0.4%	8	0.3%
Exhaust gas sens. heat	754	13.1%	314	9.2%	636	19.7%	553	18.4%
Exhaust gas dust sens. heat	25	0.4%	21	0.6%	18	0.6%	29	1.0%
Clinker	59	1.0%	50	1.5%	63	2.0%	83	2.8%
Cooler waste air	100	1.7%	276	8.1%	423	13.1%	288	9.6%
Radiation and convection :								
- Preheater	0	0.0%	160	4.7%	77	2.4%	60	2.0%
- Precalciner (or bottom stage)	0	0.0%	0	0.0%	20	0.6%	20	0.7%
- Kiln (+tertiary air duct)	530	9.2%	200	5.8%	200	6.2%	200	6.6%
- Cooler	10	0.2%	92	2.7%	10	0.3%	10	0.3%
Water cooling	0	0.0%	42	1.2%	0	0.0%	0	0.0%
Other outputs	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Rest	152	2.6%	14	0.4%	13	0.4%	12	0.4%
Total outputs	**5750**	100%	**3425**	100%	**3223**	107%	**3013**	100%



CC-99080.dsf / Kma 24.2.99

"HOLDERBANK"
Process Technology

HISTORICAL DEVELOPMENT

Annex 1

The word cement is more than 2000 years old, but impure lime has been used much longer as a building material. It is historically established, that the Phoenicians used a pozzolanic lime about 700 B.C. and also the Romans produced some sort of cement or hard burned lime. From the medieval ages, it is known that in Holland a type of hydraulic cement was formed out of lime and tuff in dome shaped kilns.

Our cement, as we know it today, is now more than **200 years** old, "invented" by the Englishman **John Smeaton in 1756.** It was burned in bottle kilns. The better known inventor of Portland cement was **Joseph Aspdin,** who patented his burning process in **1824.** He also used dome kilns of approx. 36 ft height and 17 ft diameter with a production of 90 bbl (= 15 t) per charge, each of which took several days to produce. Fuel consumption was 50% of clinker weight in coal which corresponds to 15'500 kJ/kg cli (= 3'700 kcal/kg cli).

In **1880** an important step forward was made with the development of the **continuously** working shaft kiln, which had a much better heat economy. An example of such a kiln was the "Dietzsche Etagenofen" which is shown in Annex 1.

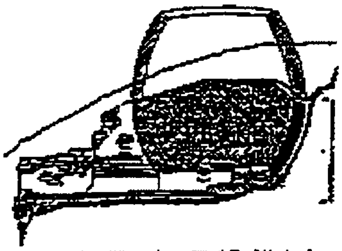
From **1877** experiments have been conducted with rotary kilns. In **1897** Hurry and Seaman developed the first successfully operating unit of this type in America.

These first rotary kilns were wet process kilns with a daily capacity of 50 to 100 tons. Their heat consumption was again very high (about 30% of clinker in coal = 9'500 kJ/kg cli) and they had an incredible dust emission (usually more than one third of the whole production). In order to decrease heat consumption, chain systems were installed in wet kilns to improve heat transfer during drying. Behind long dry kilns, waste heat steam boilers were arranged for the same purpose.

It took almost another 30 years, before a further substantial reduction of heat consumption could be achieved by reducing the water content of the feed and by a better heat exchange in the preheating a calcining zone. In **1930** an officer of the army of the **tsar, Dr. Lellep,** took an important step in this direction. He developed the travelling grate pre-heater, which is fed with moist nodules. This invention was taken over by Polysius and got the name **LEPOL** kiln. Some years later, there was a Czech patent of a cyclone raw meal pre-heater, and in **1953 Kloeckner-Humboldt-Deutz AG in Germany installed the first suspension pre-heater system for raw meal.** This type of kiln now became dominant because of its heat economy and nowadays other systems are only chosen in special cases. In former years, the main reason for the selection of the wet process was, that effective homogenisation of ground raw material was not possible except in the form of slurry. In developing special techniques for dry material homogenisation such as mix beds, mixing chamber silos etc., this factor could be eliminated.

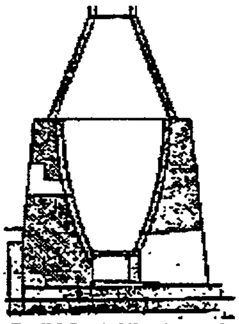
Utilising a rather old idea, since about **1966** especially Japanese cement machine manufacturers have designed several successfully working precalcining kiln systems. Calcination is already done in a stationary calciner system, where secondary firing is installed. By this means, it is possible to design kiln systems with a comparatively small rotary part diameter but a very large capacity up to more than 10'000 t/d.

Kiln systems built after 1990 include 6-stage preheaters with up to 4000 t/d per string, pure air calciners, designed for a variety of fuels and emission control. Using modern low primary air burners, low pressure drop cyclone designs and high recuperation efficiency coolers allow further reduction of heat and power consumption.

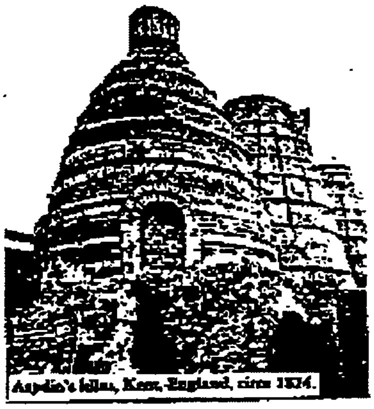


Roman lime kiln, circa 50 A.D. Vindonissamuseum Switzerland.

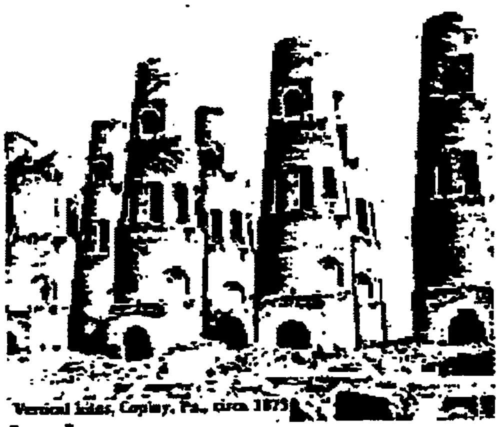
Thirteenth century burning



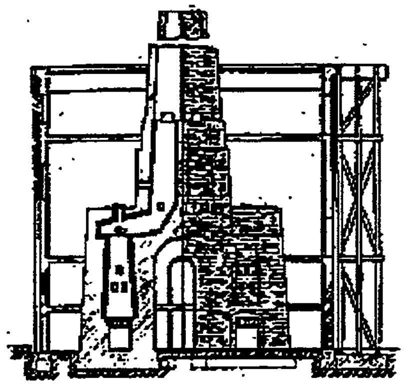
English bottle kiln, circa 1750



Aspdin's kilns, Kent, England, circa 1824.

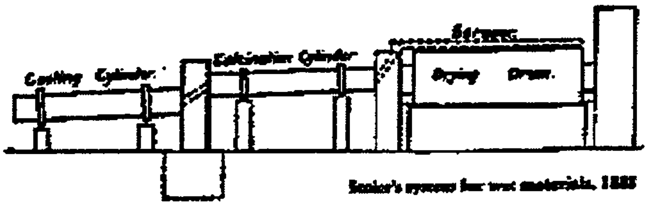


Vertical kilns, Copley, Pa., circa 1875

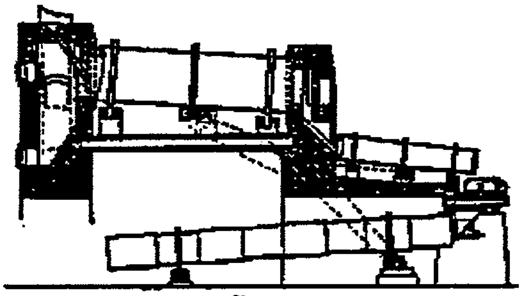


Dietzsch' multi stage shaft kiln

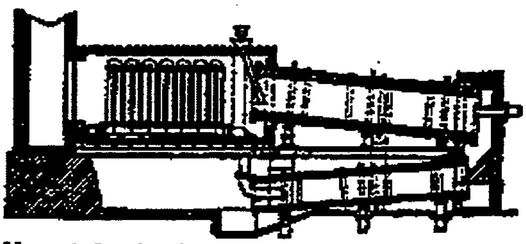
The original rotary kiln; Ransome's patent of 18[illegible]



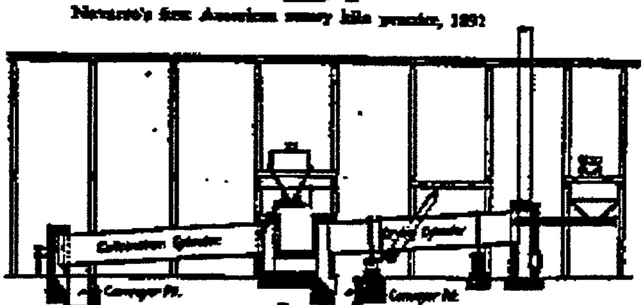
[illegible]'s system for wet materials, 18[illegible]



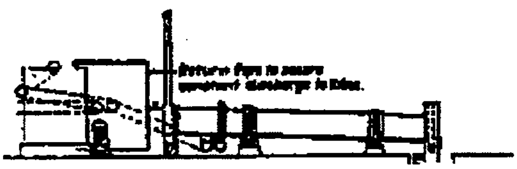
First successful rotary kiln arrangement, developed by Hurry and Seaman in 189[illegible].

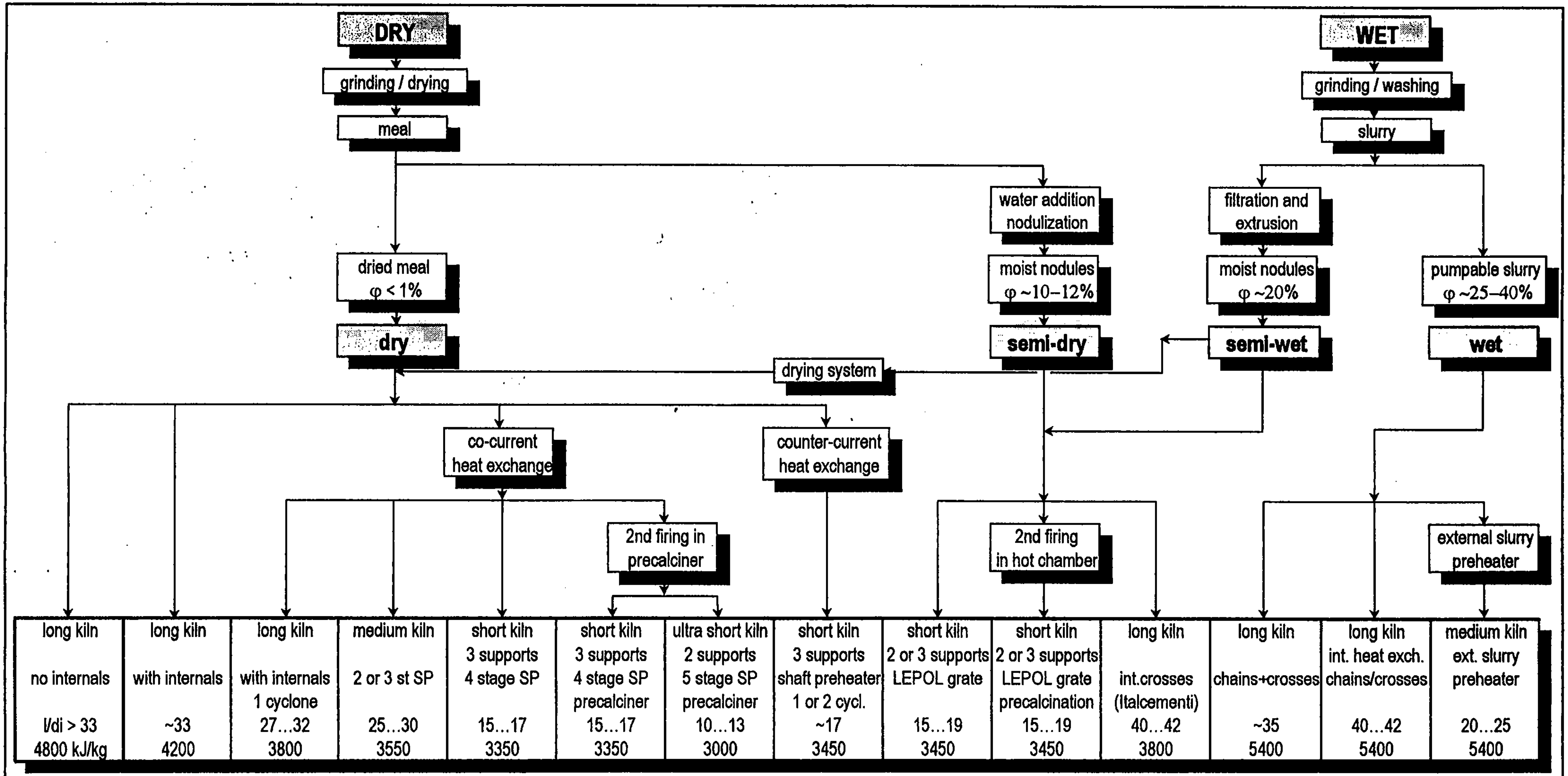


Navarro's first American rotary kiln practice, 189[illegible]



[illegible]'s first attempt at a wet-process rotary kiln, 18[illegible]





General Overview of Process Types and Rotary Kiln Systems

"HOLDERBANK"
PROCESS TECHNOLOGY

HEAT BALANCE

WET / SEMI-DRY / 4-ST. PREHEATER / 5-ST. PREHEATER-PRECALCINER

		WET PROCESS		SEMI-DRY LEPOL		4-STAGE SP		6-STAGE SP-PC	
Input		kJ/kg cli	%	kJ/kg cli	%	kJ/kg cli	%	kJ/kg cli	%
Fuel kiln	combustion	**5560**	96.7%	**3343**	97.6%	**3150**	97.7%	**1180**	39.2%
	sensible heat	25	0.4%	15	0.4%	13	0.4%	5	0.2%
Fuel PC	combustion	0	0.0%	0	0.0%	0	0.0%	**1775**	58.9%
	sensible heat	0	0.0%	0	0.0%	0	0.0%	8	0.3%
Kiln feed	sensible heat	25	0.4%	30	0.9%	54	1.7%	45	1.5%
	sensible heat of water	73	1.3%	17	0.5%	0	0.0%	0	0.0%
Insufflated air (primary, cooler)		67	1.2%	20	0.6%	6	0.2%	0	0.0%
Total inputs		**5750**	100%	**3425**	100%	**3223**	100%	**3013**	100%

Output	kJ/kg cli	%	kJ/kg cli	%	kJ/kg cli	%	kJ/kg cli	%
Heat of formation	1750	30.4%	1750	51.1%	1750	54.3%	1750	58.1%
Water evaporation	2370	41.2%	506	14.8%	13	0.4%	8	0.3%
Exhaust gas sens.heat	754	13.1%	314	9.2%	636	19.7%	553	18.4%
Exhaust gas dust sens. heat	25	0.4%	21	0.6%	18	0.6%	29	1.0%
Clinker	59	1.0%	50	1.5%	63	2.0%	83	2.8%
Cooler waste air	100	1.7%	276	8.1%	423	13.1%	288	9.6%
Radiation and convection :								
- Preheater	0	0.0%	160	4.7%	77	2.4%	60	2.0%
- Precalciner (or bottom stage)	0	0.0%	0	0.0%	20	0.6%	20	0.7%
- Kiln (+tert.air duct)	530	9.2%	200	5.8%	200	6.2%	200	6.6%
- Cooler	10	0.2%	92	2.7%	10	0.3%	10	0.3%
Water cooling	0	0.0%	42	1.2%	0	0.0%	0	0.0%
Other outputs	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Rest	152	2.6%	14	0.4%	13	0.4%	12	0.4%
Total outputs	**5750**	100%	**3425**	100%	**3223**	107%	**3013**	100%